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Bold, shy, and persistent: Variable coyote response to light and sound stimuli

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ABSTRACT

To improve frightening device technology for managing predation, we examined variation in coyote (*Canis latrans*) response to visual, auditory, and combined stimuli using a behavior-contingent programmable frightening device. We hoped to gather information on the relative effectiveness of light, sound, and combined stimuli for deterring coyotes from a food resource. We exposed five pairs of captive coyotes each to one of three stimuli during a 10-day treatment period. Coyotes habituated to the three stimuli differentially ($\chi^2 = 7.8$, d.f. = 2, $P = 0.02$). Four of five coyote pairs habituated to sound treatment, one of five pairs habituated to light stimulus, and none of five pairs habituated to combined stimuli. We further examined variability in coyote response to the device and determined that social status predicted boldness; 67% (S.E. = 12%) and 33% (S.E. = 12%) of subordinate and dominant coyotes attempted to eat the protected food respectively. Similarly, 60% (S.E. = 15%) and 20% (S.E. = 18%) of subordinate and dominant coyotes habituated and ate respectively. Our findings suggest that light may be the most important component of a frightening device for coyotes, but because coyotes can be bold or persistent, significant numbers of coyotes are expected to overcome a frightening device's long-term effectiveness.

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1. Introduction

In the USA, wildlife managers are tasked with protecting privately owned livestock from publicly owned predators (Shivik and Martin, 2000). One traditional method is lethal control of offending animals, but public support of lethal control methods is decreasing while the value placed on carnivores is increasing (Mech, 1996; Reiter et al., 1999). The change in public attitude creates the need for the development and implementation of effective, non-lethal techniques for predator damage management.

An ostensibly simple initial approach is to frighten predators away using novel stimuli (Shivik, 2006). Frightening devices rely on an animal's avoidance of a perceived danger (Linnell et al., 1996), and there are numerous methods for repelling animals with novel stimuli (Bomford and O'Brien, 1990; Linhart et al., 1992); some methods can be as simple as hanging flagging around a resource (Mettler and Shivik, 2007), but others include radio monitors and complicated triggers which activate frightening devices (Breck et al., 2003; Shivik et al., 2003a,b; VerCauteren et al., 2003). More complicated devices that use several types of stimuli simultaneously may improve effectiveness (Koehler et al., 1990; Mason et al., 2001), but when two stimuli are presented simultaneously, one stimulus may be more salient and largely responsible for the repellent effect (Schwartz and Robbins, 1995).

Although animals generally are wary of novel objects in their environment, they will usually habituate (i.e., learn to be less fearful) and stop being repelled (McCullough, 1982) unless the stimulus is accompanied by a sufficiently

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noxious negative reinforcement (Schwartz and Robbins, 1995; Conover, 2002; Gilsdorf et al., 2002). Thus, long-term effectiveness of frightening devices is prevented by habituation. Another approach for reducing habituation is to use behavior-contingent activation; a behavior-contingent repellent device is activated by a particular behavior of a predator, for example approaching a pasture (Shivik and Martin, 2000).

Elaborate devices with multiple stimuli and predator-sensing inputs could be biologically effective for repelling predators, but because each additional component of a frightening device adds to its cost, complexity and size, some devices could be too expensive and complicated to use in field conditions. If the repellent effect of multiple stimuli is not additive or synergistic, however, the complexity of frightening devices can be reduced. Therefore, more research is required to provide information that allows for optimization of repellent stimuli in order to develop an optimized (i.e., the most repellent while having the lowest cost and complexity) frightening device.

Another factor remains, however, that could influence the effectiveness of repellent stimuli: behavioral variation within the species being repelled. For example, boldness can be described as a propensity to take risk or to investigate potentially dangerous novel stimuli; individuals' behavioral responses fall along a bold–shy continuum (Wilson et al., 1994). Animals that are bolder should exhibit less susceptibility to frightening devices than shy individuals. In regard to coyotes, the boldness of particular animals is important because bold canids may ascend to a high social rank and have a particular propensity for killing livestock (Knowlton et al., 1999). To develop an optimized frightening device, studies that investigate potential repellency of particular stimuli while accounting for individual variation in behavior (i.e., boldness) may be necessary.

The purpose of our research was to gather information on the relative importance of electronically produced stimuli for deterring coyotes from a food resource. Secondarily, we examined the effectiveness of stimuli in the context of individual variation in coyote responses. Specifically, we wanted to test the hypotheses that there would be no difference between the proportion of coyotes that habituate to light, sound, and combined light and sound stimuli, and all coyotes habituate at similar times to initially repellent stimuli.

2. Methods

2.1. Subjects

We used 15 breeding pairs of experimentally naïve captive coyotes at the National Wildlife Research Center, Predator Research Facility in Millville, Utah, USA. All were captive-bred and males ranged from 4 to 9 years old and females 4 to10 years old. Captive coyotes were preferred for this study so we could closely monitor behaviors of known (i.e., sex, age, level of dominance) individuals and so we could control for confounding factors such as access to alternative foods. Previous research indicated that the behavioral budgets (i.e. proportion of time spent performing specific activities) of captive coyotes at the Predator Research Facility are similar to those of free-roaming coyotes (Gilbert-Norton, 2004; Palmer, 2005) and thus inference to wild populations is valid.

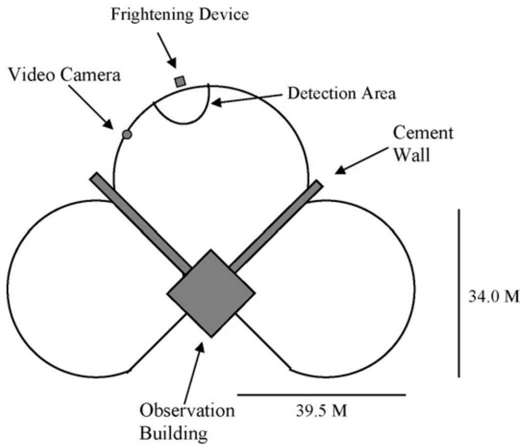

Fig. 1. Diagram of three of the 0.1 ha clover pens at the National Wildlife Research Center, Predator Research Facility (Millville, UT, USA).

Throughout the study, each pair of coyotes was housed separately in a 0.1 ha, teardrop-shaped outdoor pen (Fig. 1), spaced on average 8.8 m apart (range 4–11 m) and fed 575 g. of commercial mink food (FBAC, Logan, UT, USA) 6 days per week during morning hours. Coyote response was recorded using infrared illuminating cameras (Supercircuits Model PC-125EX, Supercircuits, Liberty Hill, TX, USA), and real time video recorders (Sanyo Model SRT-612DC, Sanyo, Chatsworth, CA, USA; Mitsubishi Model HS-128OU, Mitsubishi Electric & Electronics USA, Inc., Cypress, CA, USA; Event Model TEV-1000N, Supercircuits, Liberty Hill, TX, USA). We mounted the infrared cameras 2.1 m above the ground on the pens' fence posts, and 10.5 m from the frightening devices. We placed the cameras in the pens 7 days prior to the initial reference period so coyotes could habituate to them before the start of treatment periods. Testing was conducted from 17 July to 31 August 2005.

2.2. Comparing responses to stimuli

Our frightening device was a behavior-contingent scare/call device (SC-1, ML Designs, Goleta, CA, USA) which was activated by a motion sensor (Fig. 2). At the start of each night trial, SC-1s were placed 0.3 m above the ground against the chain link fencing on the outside of each pen. After each trial the SC-1s were removed. Frightening devices were programmed for three treatment stimuli: (1) white noise (100 dB at 2 m), (2) strobe light (400 cd), or (3) noise and light combined. The motion sensors were set to detect motion within 2 m of the frightening device. The duration of stimulus following activation of the frightening device was 20 s. We placed 54 g of processed pork divided into three pieces 1 m away from the frightening device. Trials lasted for 1.5 h each evening and began when food was placed in the pen. We analyzed video from each trial to determine latency to eat (i.e., the interval (days) between food being placed in the pen and the first coyote

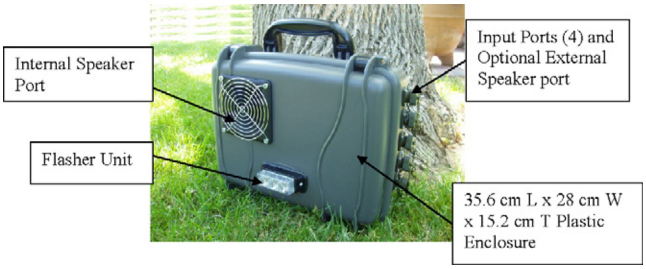

Fig. 2. SC-1 frightening device used to examine variation in captive coyote response to sound and light stimuli.

eating), the number of coyotes receiving each stimulus that ate the processed pork, as well as number of times the frightening device was activated by approaching coyotes.

With 15 pairs of coyotes, we used a balanced factorial design and randomly assigned five pairs of coyotes to the light treatment, five pairs to the sound treatment, and five to the combined light and sound treatment. Initial treatments were preceded by an 8-day reference period in which processed pork was placed in the pen with the frightening device present but not turned on to ensure that coyotes would eat the processed pork and also control for the presence of the cameras and a quiescent frightening device. During the reference period we recorded whether at least one of coyotes in each pair ate the processed pork. At the end of the 8-day reference period all coyotes were fasted for 24 h before the start of the 10-day treatment period. During the treatment period, the motion activated frightening device was turned on at the start of the evening trial when food was placed in the pen. All coyotes were again fasted for 24 h on the 8th day of the treatment period. Because all coyotes were fasted, they were assumed to be similarly motivated to eat the processed pork during the treatment. We used a single factor ANOVA (Zar, 1999, p. 184) to compare latencies between treatments using the pairs of coyotes as the sample units. We also used χ^2 test of homogeneity of proportions (SAS Institute Inc., Cary, NC, USA) to compare proportions of coyotes that habituated to each treatment (Zar, 1999, p. 470).

2.3. Categories of dominance and boldness

During experimental trials, we used videography to determine which coyote within the breeding pair activated the frightening device. We determined social status using observations of pairs during two post-experimental feeding trials conducted the subsequent 2 days following the last treatment period. We defined the dominant coyote as the one in the pair that would gain control of, eat, and prevent access by the other coyote to a single serving of their normal maintenance food. These trials were conducted after the experimental trials so that we were blind to dominance ranking during experiments.

For analyses that examined differences between individual coyotes, and not differences in mean coyote response to light, sound, and combined stimuli, we performed two additional trials in a balanced cross-over design. That is, a series of three, 10-day periods was used to expose all pairs of coyotes to all treatment stimuli separated by 8-day rest periods in which the coyotes were given the processed pork but the SC-1 was not turned on. We used means and standard errors to compare the number of frightening device activations (i.e., attempts to obtain the food) between dominant and subordinate coyotes. We also used proportions and standard errors of coyotes in each category to identify trends in frightening device activations and food consumption. To classify individual coyotes within the bold–shy continuum, we graphically examined coyote response on the axes of the number of days before eating the processed pork versus the number of attempts (i.e. number of times coyotes activated the frightening device) to eat the processed pork.

2.4. Potential confounding factors

We performed additional *post hoc* analyses to examine possible confounding variables in our experiments. For potential effects of sex, we used means and standard errors to compare the number of frightening device activations (i.e., attempts to obtain the food) between male and female coyotes. For age effects, we used simple linear regression to determine if there was a dependent relationship between age and the number of times a coyote activated the frightening device or ate. Similarly, because treatments were arranged in such a way that they were visible and audible to coyotes in other experimental pens, we used simple linear regression to determine if the distance from other pens with frightening devices influenced the number of times a coyote activated the frightening device or ate.

3. Results

3.1. Comparing responses to stimuli

At least one coyote within all 15 pairs of coyotes ate the pork product during the initial reference period. However, during the treatment periods, only one coyote within the pair activated the scare device and attempted to eat the pork product while the other member of the pair avoided the area. We did not detect a significant difference in the mean number of total device activations among treatments (light, $\bar{x} = 62$, S.E. = 38; sound, $\bar{x} = 91$, S.E. = 18; combined, $\bar{x} = 33$, S.E. = 15) ($F_{2,12} = 1.26$, $P = 0.32$). However, we detected a significant difference in the number of coyotes that ate ($\chi^2 = 7.8$, d.f. = 2, $P = 0.02$) among treatments. Specifically, coyotes were more likely to eat the food when receiving the sound only stimulus (80% ate, S.E. = 0.18) but less likely to eat when receiving the light only (20% ate, S.E. = 0.18) and light and sound combined (0% ate). Two coyotes receiving the sound only stimulus ate the pork product at 557 and 217 s on the first night of the treatment period. One coyote receiving the light only stimulus ate the pork product at 1366 s on the first night. On the 8th and 10th day of the treatment period, two additional coyotes receiving the sound only stimulus ate the pork product at 3162 and 1280 s respectively.

3.2. Categories of dominance and boldness

Because only one coyote within the pair attempted to eat the processed pork, we were able to compare dominance and boldness among the coyotes that attempted to eat the processed pork. Social status appeared to influence a coyote's tendency to activate the device (dominant, $\bar{x} = 0.33$, S.E. = 0.12, $n = 15$; subordinate, $\bar{x} = 0.67$, S.E. = 0.12, $n = 15$). Of the coyotes that activated the frightening device, a greater proportion of subordinate coyotes ate the food (dominant, $\bar{x} = 0.20$, S.E. = 0.18, $n = 5$; subordinate, $\bar{x} = 0.60$, S.E. = 0.15, $n = 10$).

We observed distinct groups of coyote's personalities on a bold–shy continuum among the coyotes in our study(Fig. 3): three bold coyotes ate on the first night and activated the frightening device more than 110 times each ($\bar{x} = 149$, S.E. = 31.26); four coyotes eventually ate and activated the frightening device more than 65 times each ($\bar{x} = 82$, S.E. = 11.51); eight coyotes did not eat the processed pork during the 30 days of testing and activated the frightening device less than 52 times each ($\bar{x} = 20$, S.E. = 5.34).

3.3. Potential confounding factors

Proportions of coyotes that activated the devices were similar between sexes (males, $\bar{x} = 0.47$, S.E. = 0.13, $n = 15$; females, $\bar{x} = 0.53$, S.E. = 0.13, $n = 15$). However, five of the eight female coyotes (63%, S.E. = 0.17) that activated the frightening device ate the food and two of the seven (29%, S.E. = 0.17) male coyotes that activated the frightening device ate the food.

We did not detect a relationship between age of the activating coyote and the number of times the coyote activated the frightening device ($P = 0.51$, $R^2 = 0.03$), nor did we detect a relationship between the distance from another pen with a frightening device and the number of times a coyote activated the frightening device ($P = 0.16$, $R^2 = 0.15$). Similarly, we did not detect a relationship between the distance from another pen with a frightening device and the probability the coyotes would eat ($P = 0.2$, $R^2 = 0.12$).

4. Discussion

Individual coyotes habituated to the frightening differentially, and the sound stimuli produced by the SC-1 appeared to be less repellent to coyotes at night than light or light and sound stimuli combined. Our results are consistent with studies using other stimuli; for example, Wells and Lehner (1976) and Wells (1978) concluded that a coyote's visual sense plays a greater role in information gathering than its auditory sense when hunting for food. Thus, for future frightening device designs, a sound component may not be necessary if the goal is to repel coyotes from an area or disrupt an attack at night. Omitting the sound stimulus could help to decrease the cost of the frightening device and wildlife managers and livestock producers may be more willing to use a less expensive and intrusive frightening device to alleviate damage. However, we tested only one type of light stimulus and one type of sound stimulus, so inferences to other frightening devices may be limited. The response to light and sound together did not significantly increase the effectiveness of these stimuli which supports the Schwartz and Robbins (1995) theory that the effects of compound stimuli are not additive or synergistic, rather the animal simply responds to the most salient stimulus.

Because behavioral budgets of captive coyotes mimic those of free-roaming coyotes (Gilbert-Norton, 2004; Palmer, 2005) captive animals are useful for evaluating frightening devices, but other elements of our experiment limited our inferences. For example, behavior-contingent frightening devices can protect a motionless food bait, but protection of livestock may be more difficult because movement by a prey item may elicit a chase response (Connolly et al., 1976) which could overpower or limit the repellency of a frightening device. Also, hunger may be greater in free-roaming coyotes than in captive coyotes causing a greater motivation to eat and therefore a greater propensity to habituate to frightening devices. Future

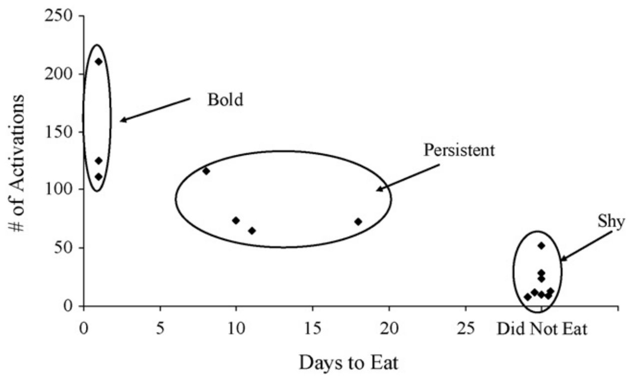

Fig. 3. Captive coyotes' activation of a behavior-contingent frightening device when attempting to obtain food. Latency to device activation and eat indicated personality type. Each point represents a pair of captive coyotes.

research should examine these factors and measure the range of effectiveness of behavior-contingent frightening devices to repel free-roaming coyotes.

In the context of eating a food protected by a frightening device, subordinate coyotes demonstrated greater boldness in activating the frightening device than dominant coyotes. To a lesser extent, female coyotes were bolder than male coyote in eating the food in the presence of the frightening device, but the difference in proportions of females and males that ate the food was probably related to social status because female coyotes were more often (73%) subordinate. Our results support the findings of Johnson and Balph (1990) that social status affects the animal's vulnerability to novel conditions, with subordinate coyotes being more likely to initiate eating in unfamiliar settings than dominant coyotes. Because dominant coyotes often control preferred resources, subordinate coyotes may exploit resources in dangerous or novel situations in an effort to obtain food (Johnson and Balph, 1990). Incidentally, in our study, three dominant coyotes ate the food during the reference period, but avoided the area during the treatment periods, while the subordinate coyote approached the food during the treatment period. Our results are contrary to Mettler and Shivik's (2007) findings that dominant, captive, coyotes were more likely to eat a food protected by fladry (a string of flags hung above the ground intended to deter wildlife) than subordinate coyotes. The differences between studies could have been due to differences in experimental design, or the difference may be more complicated and require additional research.

The coyotes in our study fitted well into three categories: bold, persistent, and shy (Gosling, 1998). To effectively categorize coyotes (and other predators), we measured behavioral responses in terms of both habituation and persistence in response to the frightening device. We conclude that bold coyotes are those that immediately overcome a frightening stimulus and tend not to avoid it. Alternatively, shy animals are those that not only fail to habituate to a frightening stimulus, but also tend to avoid the frightening stimulus. Persistent animals are not bold because they are initially repelled by frightening stimuli (similar to shy coyotes), but they are not shy because they tend to not avoid the frightening stimuli (similar to bold coyotes). McGrew and Blakesley (1982) similarly reported variability in the persistence and aggression of coyote in attacking sheep protected by guard dogs. We hypothesize that free-roaming coyotes will exhibit individual behavioral variation such that some will usually be successfully repelled using frightening devices, some fail to be repelled, and some will initially be repelled but persist and eventually learn to overcome the repellency of the devices.

Identifying which coyotes are most bold is as important as identifying which coyotes kill sheep when developing effective frightening devices. If the same coyote that is likely to overcome the deterrent stimulus is the most likely to kill livestock, then frightening devices will not be effective. For example, the dominant coyotes that are most likely to kill sheep (Sacks et al., 1999a) are also less vulnerable for removal methods than lower ranking animals or transients (Sacks et al., 1999b) and thus many current management methods may select for animals that are not causing problems.

5. Conclusion

Our results suggest light is a better repellent than sound for coyotes, but the effectiveness of frightening devices is dependent upon social status and boldness of individual coyotes. Because light stimulus and combined light and sound stimuli are repellent to some bold coyotes, which are often responsible for livestock depredation, frightening devices can be effective at reducing predation on livestock. However, because some coyotes are persistent in testing the frightening device and eventually habituate, long-term effectiveness of a frightening device may limited.

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